PERFORMANCE OF ANNUAL LEGUME GREEN MANURE CROPS AT SASKATOON

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Abstract

Four annual legumes, lentil (Lens culinaris cv. 'NEL-481'), field pea (Pisum sativum cv. 'Trapper'), faba bean (Vicia faba cv. 'Outlook') and Tangier flatpea (Lathyrus tingitanus cv. 'Tinga'), and one perennial, alfalfa (Medicago sativa cv. 'Moapa') were compared over three growing seasons for their suitability as annual green manure crops grown in the fallow year of a wheat-fallow rotation. As nitrogen fixation usually declines after seed set, crop growth was stopped by cultivation or desiccation during early pod filling. This terminated further use of available soil moisture, conserving it for the following grain crop. Mean seasonal nitrogen fixation ranged from 2 to 40 kg/ha. However, the mean total nitrogen in the top growth at plowdown, ranged from 15 to 114 kg/ha. The measured nitrogen fixation accounted for 13 to 42% of the above ground nitrogen. There was little difference in water use among the legume crops.

Introduction

Legumes and legume-grass mixtures in the rotation add organic matter to the soil, increase available nitrogen, improve soil structure, reduce leaching of plant nutrients, reduce soil and water losses, reduce salinization, and often increase the yield of succeeding crops. However, they deplete soil moisture reserves, provide low economic returns, compete poorly with weeds and are expensive and difficult to establish (Slinkard 1983).

Peiters (1917) noted that in the Northern Great Plains alfalfa (Medicago sativa) and biennial sweetclover (Melilotus spp.) green manure crops reduced the yield of succeeding crops by depleting the available soil moisture beyond the rooting depth of spring wheat. The newly broken fields were capable of supplying enough nitrogen to support a crop, but moisture limited production. He concluded that legume green manure crops should not be used in the Northern Great Plains.

Forty years later Army and Hide (1959) likewise concluded that green manures should not be used for the production of spring or winter wheat on

Brown or Dark Brown soils with present cultural techniques. Brown (1964) also concluded that legume green manure crops such as alfalfa and biennial sweetclover should not be used in short rotations on Class I, II and III land in the Brown and Dark Brown soil zones. However, legume green manure crops had a beneficial effect on succeeding crops in short and long rotations in the Black and Gray soil zones (Bowren and MacNaughton 1967, Bowren and Cooke 1975). Brown (1964) also noted that green manure-fallow often outyielded conventional fallow in wet years or more humid areas or when early incorporation of the green manure permitted conservation of more moisture.

Poyser et al. (1957) showed that, as soil organic matter and thus the nitrogen supplying power of the soil declined over 25 years of cultivation, the benefits of legume green manure crops in a 4-year rotation increased. The soils with legume green manures, particularly with peas, the only annual, showed a slower decline in soil organic matter and nitrogen content.

Perennial legumes consistently fix more nitrogen than annuals, but they often deplete soil moisture reserves to the extent that moisture, not nitrogen, limits production, and thus the extra nitrogen is of little benefit. The use of annual legumes or perennials managed as annuals would allow nitrogen fixation without depletion of soil moisture reserves. An annual legume green manure crop could supply up to 50 kg/ha of nitrogen to the succeeding grain crop (Slinkard 1983). Accordingly, the objective of this study was to determine the potential of annual legume crops for green manure in the Dark Brown soil zone.

Materials and Methods

In the first year (1983) of the study, Tangier flatpea (*Lathyrus tingitanus* cv. 'Tinga') with and without inoculum, lentil (*Lens culinaris* cv. 'Eston'), field pea (*Pisum sativum* cv. 'Trapper') and faba bean (*Vicia faba*

'Outlook') were seeded twice in each of six replicates. One plot of each was incorporated while the other was desiccated at the beginning of seed set. Each replicate contained a spring wheat (*Triticum aestivum* cv. 'Neepawa') plot and a summer fallow plot as controls. Randomization was restricted by placing all of the incorporation treatments and all of the desiccation treatments together, in order to facilitate field operations. This also effectively doubled the replication for measurements of the legumes taken before incorporation.

As no difference in nitrogen fixation and growth was found in the uninoculated and inoculated flatpea, the uninoculated treatment was dropped in favor of a non-hardy alfalfa (*Medicago sativa* cv. 'Moapa'). The breeder line NEL-481 was substituted for Eston in the lentil treatment when sufficient quantities of seed became available in the second year of the experiment.

Seeding in all three years was completed by mid-May. In 1983, 26 cm of snow fell on the freshly seeded crop.

Three to six sets of field samples were taken on one to two week intervals during each growing season between mid-June and crop incorporation at the end of July. Nitrogen fixation was estimated by acetylene reduction in the field. The roots of three plants were placed in a jar with enough acetylene to give a 5% acetylene atmosphere. At the end of the incubation time a sample was taken using evacuated 10 mL blood sample containers. The sample was analysed by gas chromatography.

The rate of acetylene reduction was converted to nitrogen production and integrated over the time interval between measurements to estimate the total nitrogen fixed by each plant.

The top growth of the excavated plants was dried and weighed. The material from the last sample before incorporation was ground and its nitrogen content determined by micro-Kjeldahl in the first year and by digestion and autoanalyser in the remaining years.

Stand density, derived from stand counts, was used to convert plant dry weight, nitrogen content and nitrogen fixation from an individual plant basis to an area basis.

In 1983 and 1985 soil moisture to a depth of approximately 1 m was measured in the spring and fall. The differences in soil moisture at the beginning and end of the growing season, coupled with the precipitation provided an estimate of water consumption and water use efficiency of nitrogen fixation.

The plots were seeded to wheat following the green manure crops to determine the effect of green manure on yield and protein.

The data were analysed by analysis of variance. As all of the plant weights and nitrogen fixation data exhibited heterogenity of variances, the analysis was conducted on log transformed data.

Results

The top growth (dry matter) of individual plants was highest in 1983; the 1984 and 1985 means were similar (Figure 1). In 1983, the faba bean had the largest plant dry matter, followed by field pea, lentil and Tangier flatpea. In the remaining years the pea and bean plants were equal in dry matter, followed by lentil and Tangier flatpea which were similar. Alfalfa had the smallest plant dry matter.

Top growth (dry matter) on an area basis was also highest in 1983 in all species except Tangier flatpea, which had a poor stand (Figure 2). Faba bean also had a poor stand in 1984 which reduced its top growth. Field pea was highest in all three years, but only in 1983 was it significantly higher than all other legumes. Faba bean, lentil and Tangier flatpea have similar dry

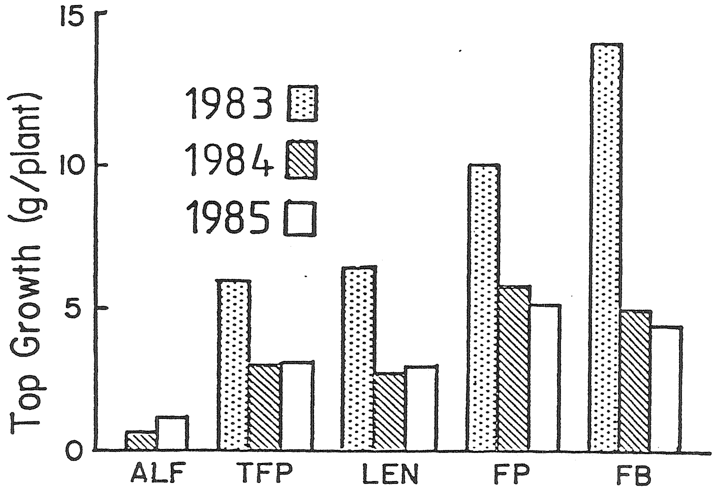

Fig. 1. Dry weight (g/plant) of the top growth of Alfalfa (ALF), Tangier flat pea (TFP), Lentil (LEN), Field pea (FP) and Faba bean (FB) green manure crops at time of incorporation in 1983, 1984 and 1985.

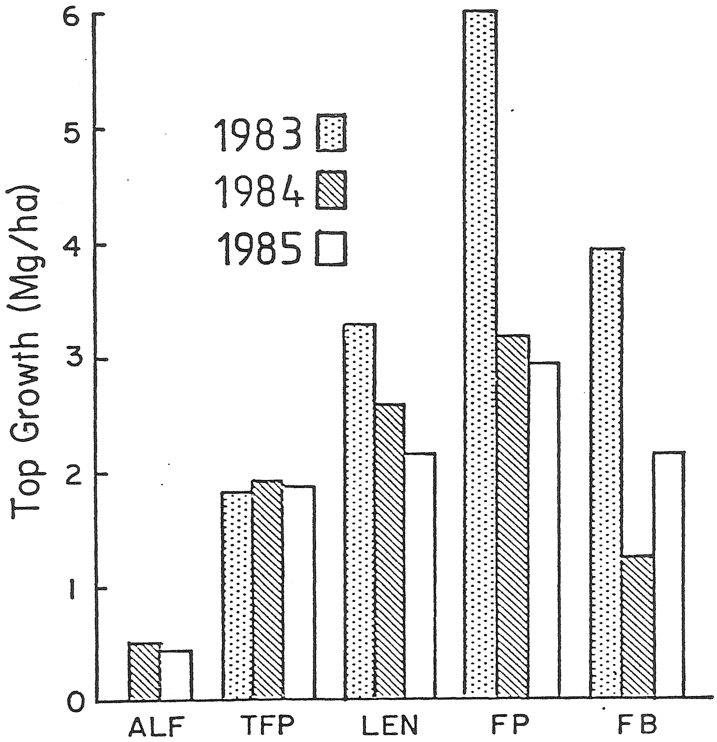

Fig. 2. Dry weight (kg/ha) of the top growth of Alfalfa (ALF), Tangier flat pea (TFP), Lentil (LEN), Field pea (FP) and Faba bean (FB) green manure crops at time of incorporation in 1983, 1984 and 1985.

matter yields. Alfalfa was substantially lower than all other treatments.

The amount of nitrogen in the top growth of individual plants follows a similar pattern to plant weight. The highest levels were recorded in 1983, with 1984 and 1985 lower and equal to each other (Figure 3). Faba bean was higher than pea in 1983 and equal in the other years. Lentil and Tangier flatpea were lower than pea and equal to each other. Alfalfa contained a much lower amount of nitrogen in the top growth than the other crops.

The amount of nitrogen in the top growth, on an area basis, was highest in 1983 and equal in 1984 and 1985 except in faba bean where a thin stand in 1984 reduced the level (Figure 4). The amount of nitrogen in the pea top growth was higher than all other treatments, but the difference was significant only in 1983. In the other two years lentil was not significantly lower. The lentil, Tangier flatpea and faba bean form a group which is only slightly lower than the field pea. Alfalfa had significantly less nitrogen in the top growth than all other species.

Except for field pea, the quantity of nitrogen fixed by individual plants was reduced in 1984, which was very dry (figure 5). The quantity of nitrogen fixed by individual faba bean plants was higher than all other species in 1983 and 1985. Field pea was next, followed by Tangier flatpea, lentil and alfalfa. Both alfalfa and lentil fixed less than would be expected for plants of their size as fixation accounted for much less of their above-ground nitrogen (Figure 6). Both of these plants have relatively fine roots and many small nodules. The rest have relatively large nodules on more robust roots and thus are easier to recover in excavation.

Field pea had the highest nitrogen fixation on an area basis except in 1985 when faba bean was the highest (Figure 7). Nitrogen fixation by the faba bean was the least stable. Low rates coupled with a thin stand in 1984

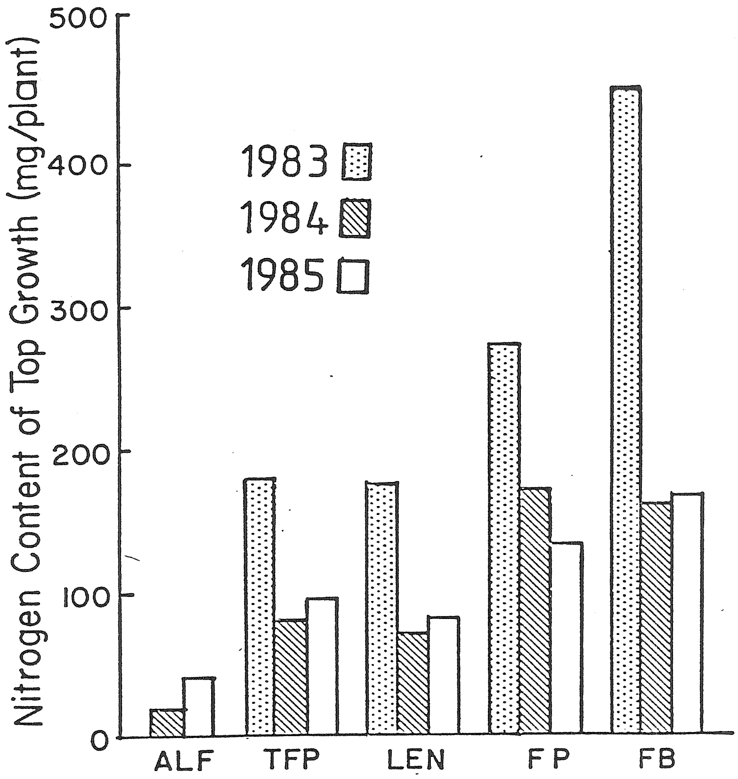

Fig. 3. Nitrogen content (mg/plant) of the top growth of Alfalfa (ALF), Tangier flat pea (TFP), Lentil (LEN), Field pea (FP) and Faba bean (FB) green manure crops at time of incorporation in 1983, 1984 and 1985.

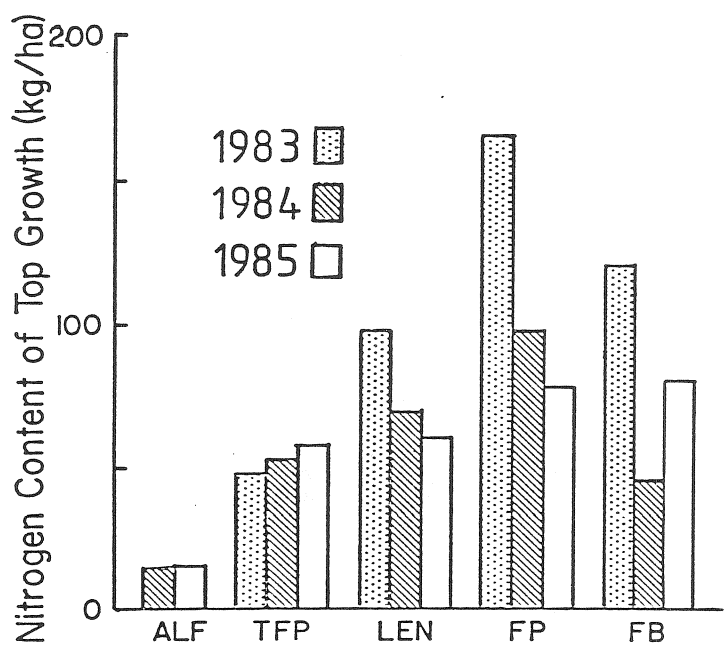

Fig. 4. Nitrogen content (kg/ha) of the top growth of Alfalfa (ALF), Tangier flat pea (TFP), Lentil (LEN), Field pea (FP) and Faba bean (FB) green manure crops at time of incorporation in 1983, 1984 and 1985.

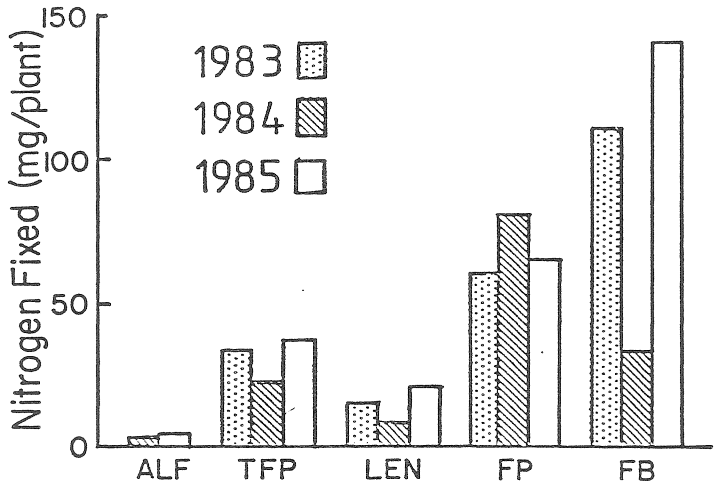

Fig. 5. Nitrogen fixed (mg/plant) by Alfalfa (ALF), Tangier flat pea (TFP), Lentil (LEN), Field pea (FP) and Faba bean (FB) green manure crops in the 1983, 1984 and 1985 growing seasons, as estimated by acetylene reduction.

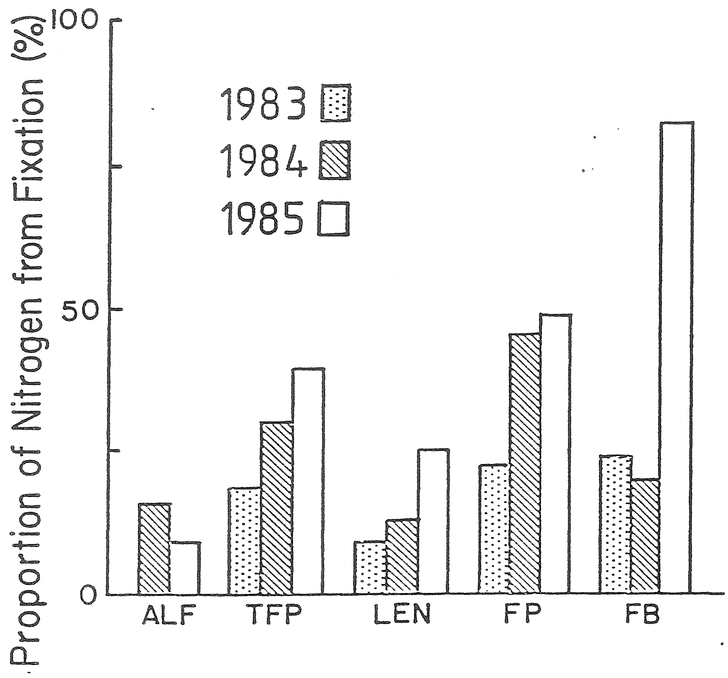

Fig. 6. Proportion of nitrogen (%) originating from nitrogen fixation in the top growth of Alfalfa (ALF), Tangier flat pea (TFP), Lentil (LEN), Field pea (FP) and Faba bean (FB) green manure crops.

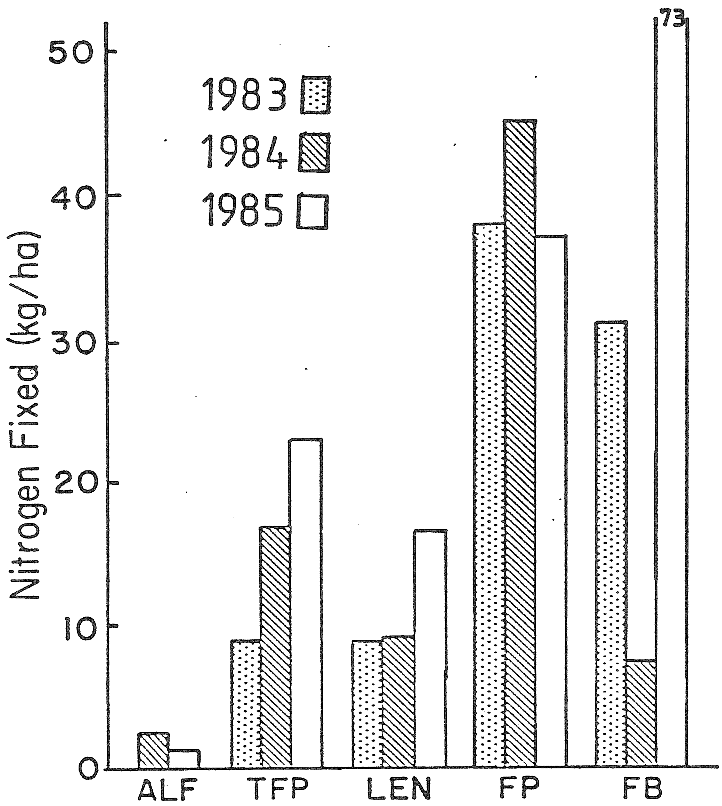

Fig. 7. Nitrogen fixed (kg/ha) by Alfalfa (ALF), Tangier flat pea (TFP), Lentil (LEN), Field Pea (FP) and Faba bean (FB) green manure crops in the 1983, 1984 and 1985 growing seasons, as estimated by acetylene reduction.

substantially reduced its fixation. Lentil and Tangier flatpea were approximately equal in fixation, while alfalfa were much lower.

As expected, summerfallow used the least water of all treatments in both years measured and wheat used slightly more than the rest except lentil (Table 1). The high water use values for 1983, were in part likely due to runoff or deep drainage, as a large part of the rainfall came in one storm in late June.

As the legumes used similar amounts of water, the water use efficiency of nitrogen fixation within a year is largely dependent on the rates of fixation.

Discussion and Conclusions

The measured nitrogen fixation rate of approximately 40 kg/ha is low compared to the 50 kg/ha predicted by Slinkard (1983). The lentil level is particularly low as it is usually a high fixer of nitrogen in comparison with other species. However, the lentil's proportion of nitrogen from fixation was low, indicating that incomplete nodule recovery for incubation could have occurred.

The apparent rate of nitrogen fixation can be calculated from the nitrogen balance. This calculation (Table 2) gives higher values for lentil and field pea as fixation does not account for the difference between soil test nitrogen and the amount of nitrogen in the top growth in these two crops.

In economic terms, a partial evaluation indicates that the value of the nitrogen fixed, as estimated by acetylene reduction, recovered almost 50% of the cost of seed in lentil and field pea, when nitrogen costs $0.65 per kg (Table 3). The other crops recovered much less. When the apparent rate of fixation is considered, lentil recovered 143% of the seed cost while field pea recovered 86% (Table 4).

Table 1. Water use and water use efficiency (WUE) of nitrogen fixation of five leguminous green manure crops, wheat and fallow, during the 1983 and 1985 growing seasons

	1983		1985	
	Water use (cm)	WUE (mg N/kg water)	Water use (cm)	WUE (mg N/kg water)
Alfalfa	--	--	14.7	0.82
Flat pea	26.5	3.5	14.4	16.1
Lentil	28.0	3.4	15.3	10.7
Field pea	24.3	15.9	14.4	26.3
Faba bean	26.2	11.9	14.6	50.0
Wheat	27.4	--	15.7	--
Fallow	21.8	--	10.6	--

Table 2. Nitrogen balance of five leguminous green manure crops (mean of three years)

	Nitrogen in soil	Nitrogen fixed*	Nitrogen in plant	Apparent nitrogen fixation**
	----------	---------- kg ha $^{-1}$	----------	----------
Alfalfa	43	2	15	-28
Flat pea	43	16	53	10
Lentil	43	11	76	33
Field pea	43	40	114	71
Faba bean	43	37	81	38

*By acetylene reduction.
**Nitrogen in plant - Nitrogen in soil.

Table 3. Partial economic evaluation of four leguminous green manure crops, comparing seed cost with value of nitrogen fixed, as estimated by acetylene reduction (3 year mean)

Crop	Seed cost ($/ha)	Value of Nitrogen fixed ($/ha)	Benefit/Cost
Flat pea	66	10.66	0.16
Lentil	15	7.35	0.49
Field pea	53	26.20	0.49
Faba bean	92	24.25	0.26

Table 4. Partial economic evaluation of four leguminous green manure crops, comparing seed cost with value of nitrogen fixed, as estimated by nitrogen balance (3 year mean)

Crop	Seed cost ($/ha)	Value of Nitrogen fixed ($/ha)	Benefit/Cost
Flat pea	66	6.5	0.10
Lentil	15	21.45	1.43
Field pea	53	45.50	0.86
Faba bean	92	24.96	0.27

The economic benefit will improve as the price of nitrogen fertilizer increases, the cost of green manure seed decreases, the productivity of nitrogen fixers is improved and the value of long term benefits accumulate.

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